

What is claimed:

1. A polyoxometalate topical composition for removing a contaminant from an environment, comprising a topical carrier and at least one polyoxometalate, with the proviso that the polyoxometalate is not $H_5PV_2Mo_{10}O_{40}$; $K_5Si(H_2O)Mn^{III}W_{11}O_{39}$; $K_4Si(H_2O)Mn^{IV}W_{11}O_{39}$; or $K_5Co^{III}W_{12}O_{40}$.
2. The composition of claim 1, wherein the polyoxometalate has the formula 1 of $[V_kMo_mW_nNb_oTa_pM_qX_rO_s]^y[A]$, wherein M is at least one f-block element or d-block element having at least one d-electron, wherein M is not vanadium, molybdenum, tungsten, niobium, or tantalum; X is at least one p-, d-, or f-block element, wherein X is not oxygen; k is from 0 to 30; m is from 0 to 160; n is from 0 to 160; o is from 0 to 10; p is from 0 to 10; q is from 0 to 30; r is from 0 to 30; s is sufficiently large that y is greater than zero; and y is greater than zero, wherein the sum of k, m, n, o, and p is greater than or equal to four; and the sum of k, m, and q is greater than zero, and A is one or more different counterions.
3. The composition of claim 2, wherein M comprises a d-block element having at least one d-electron or a f-block element having at least one f-electron.
4. The composition of claim 2, wherein M comprises titanium, chromium, manganese, cobalt, iron, nickel, copper, rhodium, silver, palladium, platinum, mercury, or ruthenium.
5. The composition of claim 2, wherein M comprises manganese.
6. The composition of claim 2, wherein M comprises cobalt.
7. The composition of claim 2, wherein M comprises ruthenium.

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8. The composition of claim 2, wherein M comprises copper.
9. The composition of claim 2, wherein X comprises phosphorus, silicon, aluminum, boron, cobalt, zinc, or iron.
10. The composition of claim 2, wherein A comprises a quaternary ammonium cation; proton; alkali metal cation; alkaline earth metal cation; ammonium cation; d- or f-block metal complex, or a combination thereof.
11. The composition of claim 2, wherein A comprises cerium, silver, gold, platinum, or a combination thereof.
12. The composition of claim 2, wherein A comprises hydrogen, lithium, sodium, potassium, or a combination thereof.
13. The composition of claim 2, wherein A comprises (1) hydrogen, lithium, sodium, potassium, or a combination thereof, and (2) cerium, silver, gold, platinum, or a combination thereof.
14. The composition of claim 2, wherein A is silver.
15. The composition of claim 2, wherein A is gold.
16. The composition of claim 2, wherein A is platinum.
17. The composition of claim 2, wherein A is cerium.
18. The composition of claim 2, wherein A is cerium and silver.
19. The composition of claim 2, wherein A is cerium and platinum.

20. The composition of claim 2, wherein A is cerium and gold.
21. The composition of claim 2, wherein A is silver and gold.
22. The composition of claim 2, wherein A is not hydrogen or potassium.
23. The composition of claim 2, wherein s is from 19 to 460.
24. The composition of claim 2, wherein the sum of k and q is greater than or equal to one, the sum of k, m, n, o, p, and q is 12, and s is 40.
25. The composition of claim 2, wherein k is not zero.
26. The composition of claim 2, wherein q is not zero.
27. The composition of claim 1, wherein the polyoxometalate has the formula $[X^{g+}V_b^{j+}M_c^{h+}Z_{12-b-c}^{i+}O_x]^u[A]$, wherein X is at least one p-, d-, or f-block element; g is greater than or equal to 2; M is at least one f-block element or d-block element having at least one d-electron, wherein M is not vanadium; h is from 1 to 7; i is from 5 to 6; j is from 4 to 5; x is 39 or 40; Z is tungsten, molybdenum, niobium, or a combination thereof; b is from 0 to 6; c is from 0 to 6; u is from 3 to 9; and A is a counterion.
28. The composition of claim 27, wherein the polyoxometalate has the formula $[X^{g+}V_b^{j+}Z_{12-b}^{i+}O_{40}]^u[A]$, wherein X is at least one phosphorus, silicon, aluminum, boron, zinc, cobalt, or iron; b is from 1 to 6, and u is from 3 to 9.
29. The composition of claim 27, wherein the polyoxometalate has the structure $[X^{g+}M_c^{h+}Z_{12-c}^{i+}O_{40}]^u[A]$, wherein X is at least one phosphorus, silicon, aluminum, boron, zinc, cobalt, or iron; c is from 1 to 6, and u is from 3 to 9.

30. The composition of claim 1, wherein the polyoxometalate has the formula $[X_2^{r+}V_u^{s+}M_v^{t+}Z_{18-u-v}^{y+}O_z]^{w-}[A]$, wherein X is at least one p-, d-, or f-block element; r is greater than or equal to 1; M is at least one f-block element or d-block element having at least one d-electron, wherein M is not vanadium; t is from 1 to 7; s is from 4 to 5; Z is tungsten, molybdenum, niobium, or a combination thereof; u is from 0 to 9; v is from 0 to 9; y is from 5 to 6; z is 61 or 62; w is greater than or equal to 4; and A is a counterion.
31. The composition of claim 30, wherein the polyoxometalate has the formula $[X_2^{r+}V_u^{s+}Z_{18-u}^{y+}O_{62}]^{w-}[A]$, wherein X is at least one phosphorus, sulfur, silicon, aluminum, boron, zinc, cobalt, or iron; u is from 1 to 9; and w is greater than or equal to 4.
32. The composition of claim 30, wherein the polyoxometalate has the formula $[X_2^{r+}M_v^{t+}Z_{18-v}^{y+}O_{62}]^{w-}[A]$, wherein X is at least one phosphorus, sulfur, silicon, aluminum, boron, zinc, cobalt, or iron; v is from 1 to 9; and w is greater than or equal to 4.
33. The composition of claim 1, wherein the polyoxometalate has the formula $[YV_pZ_{12-p}O_{40}]^{w-}[A]$, wherein Y is phosphorus, silicon, or aluminum; Z is tungsten or molybdenum; p is from 1 to 6, and A is a counterion.
34. The composition of claim 1, wherein the polyoxometalate further comprises an organic group, an organosilyl group, an other p-block organometallic group, or a d-block organometallic group, wherein the organic group, the organosilyl group, the other p-block organometallic group, or the d-block organometallic group is bonded to the polyoxometalate.
35. The composition of claim 1, wherein the polyoxometalate comprises $K_8Co_2W_{11}O_{39}$; $K_8SiCoVW_{10}O_{39}$; $K_7SiCoVW_{10}O_{39}$; $Na_8Co_2W_{11}O_{39}$;

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$\text{Ag}_5\text{PV}_2\text{Mo}_{10}\text{O}_{40}$; $\text{Ag}_6\text{PV}_3\text{Mo}_9\text{O}_{40}$; $\text{Ag}_8\text{CoVW}_{11}\text{O}_{40}$; $\text{Ag}_{12}\text{Ce}(\text{PW}_{11}\text{O}_{39})_2$; $\text{Na}_{12}\text{Ce}(\text{PW}_{11}\text{O}_{39})_2$; $\text{K}_{12}\text{Ce}(\text{PW}_{11}\text{O}_{39})_2$; $\text{Na}_5\text{PCuW}_{11}\text{O}_{39}$; $\text{H}_6\text{PV}_3\text{Mo}_9\text{O}_{40}$; or $\text{K}_5\text{Cu}^{\text{II}}\text{PW}_{11}\text{O}_{39}$.

36. The composition of claim 1, wherein the polyoxometalate comprises a modified polyoxometalate, wherein the modified polyoxometalate comprises the admixture of (1) a pre-modified polyoxometalate and (2) a cerium compound, a silver compound, a gold compound, a platinum compound, a copper compound, a cobalt compound, or a combination thereof.
37. The composition of claim 36, wherein (1) the pre-modified polyoxometalate is $\text{H}_5\text{PV}_2\text{Mo}_{10}\text{O}_{40}$ and (2) the cerium compound is $(\text{NH}_4)_2\text{Ce}(\text{NO}_3)_6$.
38. The composition of claim 36, wherein (1) the pre-modified polyoxometalate is $\text{H}_5\text{PV}_2\text{Mo}_{10}\text{O}_{40}$; (2) the cerium compound is $(\text{NH}_4)_2\text{Ce}(\text{NO}_3)_6$; and (3) the gold compound is HAuCl_4 .
39. The composition of claim 36, wherein (1) the pre-modified polyoxometalate is $\text{H}_5\text{PV}_2\text{Mo}_{10}\text{O}_{40}$; (2) the cerium compound is $(\text{NH}_4)_2\text{Ce}(\text{NO}_3)_6$; and (3) the platinum compound is H_2PtCl_6 .
40. The composition of claim 36, wherein (1) the pre-modified polyoxometalate is $\text{Na}_5\text{PV}_2\text{Mo}_{10}\text{O}_{40}$ and (2) the silver compound is AgNO_3 , AgClO_4 , or a combination thereof.
41. The composition of claim 36, wherein (1) the pre-modified polyoxometalate comprises $\text{Na}_4\text{PVMo}_{11}\text{O}_{40}$; $\text{Na}_5\text{PV}_2\text{Mo}_{10}\text{O}_{40}$; $\text{Na}_6\text{PV}_3\text{Mo}_9\text{O}_{40}$; $\text{Na}_5\text{H}_2\text{PV}_4\text{W}_8\text{O}_{40}$; $\text{Na}_9\text{PV}_6\text{Mo}_6\text{O}_{40}$; $\text{Na}_5\text{CuPW}_{11}\text{O}_{39}$; $\text{Na}_5\text{CuPW}_{11}\text{O}_{40}$; $\text{Na}_5\text{MnPW}_{11}\text{O}_{40}$; $\text{K}_5\text{CoPW}_{11}\text{O}_{39}$; $(\text{ndec}_4)_6\text{HMnNb}_3\text{P}_2\text{W}_{15}\text{O}_{62}$; or $\text{K}_{12}\text{Cu}_3(\text{W}_9\text{PO}_{34})_2$, and (2) the gold compound is HAuCl_4 .

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42. The composition of claim 1, wherein the topical carrier comprises a perfluorinated polymer.
43. The composition of claim 1, wherein the topical carrier comprises a perfluorinated polymer and at least one unfluorinated polymer.
44. The composition of claim 1, wherein the topical carrier comprises a perfluoropolyether.
45. The composition of claim 1, wherein the topical carrier comprises a perfluoropolyether and at least one unfluorinated polyether.
46. The composition of claim 1, wherein the polyoxometalate is from 0.01 to 95 % by weight of the polyoxometalate topical composition.
47. The composition of claim 2, wherein the topical carrier is a perfluoropolyether and A is silver.
48. A method for removing a contaminant from an environment, comprising contacting the polyoxometalate topical composition of claim 1 with the environment containing the contaminant for a sufficient time to remove the contaminant from the environment.
49. A method for removing a contaminant from an environment, comprising contacting the polyoxometalate topical composition of claim 36 with the environment containing the contaminant for a sufficient time to remove the contaminant from the environment.
50. The method of claim 48, wherein the environment comprises the gas phase.

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51. The method of claim 48, wherein the environment comprises the liquid phase.
52. The method of claim 48, wherein the contaminant comprises a chemical warfare agent.
53. The method of claim 48, wherein the contaminant comprises an aldehyde, an aliphatic nitrogen compound, a sulfur compound, an aliphatic oxygenated compound, a halogenated compound, an organophosphate compound, a phosphonothioate compound, a phosphorothioate compound, an arsenic compound, a chloroethyl-amine compound, a phosgene compound, a cyanic compound, or a combination thereof.
54. The method of claim 48, wherein the contaminant comprises acetaldehyde, methyl mercaptan, ammonia, hydrogen sulfide, methyl sulfide, diethyl sulfide, diethyl disulfide, dimethyl sulfide, dimethyl disulfide, trimethylamine, styrene, propionic acid, n-butyric acid, n-valeric acid, iso-valeric acid, pyridine, formaldehyde, 2-chloroethyl ethyl sulfide, carbon monoxide, or a combination thereof.
55. The method of claim 48, wherein when the environment is the gas phase, the contaminant is removed from the gas phase at from -50 °C to 250 °C and at a pressure of from 0.1 ppb to 30 atm.
56. The method of claim 48, wherein when the environment is the gas phase, the contaminant is removed from the gas phase at from 0 °C to 105 °C and at 1 atm.
57. A method for removing a contaminant from an environment, comprising contacting a polyoxometalate powder or a polyoxometalate coating with the environment containing the contaminant for a sufficient time to remove the contaminant from the environment.

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58. A modified polyoxometalate, wherein the modified polyoxometalate comprises the admixture of (1) a polyoxometalate and (2) a cerium compound, a silver compound, a gold compound, a platinum compound, or a combination thereof.
59. The modified polyoxometalate of claim 58, wherein (1) the pre-modified polyoxometalate is $H_5PV_2Mo_{10}O_{40}$; $Na_5PV_2Mo_{10}O_{40}$; $Li_5PV_2Mo_{10}O_{40}$; $K_5PV_2Mo_{10}O_{40}$, or a combination thereof, and (2) the cerium compound is $(NH_4)_2Ce(NO_3)_6$.
60. The modified polyoxometalate of claim 58, wherein (1) the pre-modified polyoxometalate is $H_5PV_2Mo_{10}O_{40}$; $Na_5PV_2Mo_{10}O_{40}$; $Li_5PV_2Mo_{10}O_{40}$; $K_5PV_2Mo_{10}O_{40}$, or a combination thereof; (2) the cerium compound is $(NH_4)_2Ce(NO_3)_6$; and (3) the gold compound is $HAuCl_4$.
61. The modified polyoxometalate of claim 58, wherein (1) the pre-modified polyoxometalate is $H_5PV_2Mo_{10}O_{40}$; $Na_5PV_2Mo_{10}O_{40}$; $Li_5PV_2Mo_{10}O_{40}$; $K_5PV_2Mo_{10}O_{40}$, or a combination thereof; (2) the cerium compound is $(NH_4)_2Ce(NO_3)_6$; and (3) the platinum compound is H_2PtCl_6 .
62. The modified polyoxometalate of claim 58, wherein (1) the pre-modified polyoxometalate is $H_5PV_2Mo_{10}O_{40}$; $Na_5PV_2Mo_{10}O_{40}$; $Li_5PV_2Mo_{10}O_{40}$; $K_5PV_2Mo_{10}O_{40}$, or a combination thereof, and (2) the silver compound is $AgNO_3$.
63. The modified polyoxometalate of claim 58, wherein (1) the pre-modified polyoxometalate independently comprises $Na_4PVMo_{11}O_{40}$; $Na_5PV_2Mo_{10}O_{40}$; $Na_6PV_3Mo_9O_{40}$; $Na_5H_2PV_4W_8O_{40}$; $Na_9PV_6Mo_6O_{40}$; $Na_5CuPW_{11}O_{39}$; $Na_5CuPW_{11}O_{39}$; $Na_5MnPW_{11}O_{40}$; $K_5CoPW_{11}O_{39}$; $(n-Dec_4)_6HMnNb_3P_2W_{15}O_{62}$; or $K_{12}Cu_3(W_9PO_{34})_2$, and (2) the gold compound is $HAuCl_4$.

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64. A polyoxometalate comprising $K_8Co_2W_{11}O_{39}$; $K_8SiCoVW_{10}O_{39}$; $K_7SiCoVW_{10}O_{39}$; $Ag_5PV_2Mo_{10}O_{40}$; $Ag_6PV_3Mo_9O_{40}$; $Ag_8CoVW_{11}O_{40}$; or $Ag_{12}Ce(PW_{11}O_{39})_2$.
65. A modified material for removing a contaminant from an environment, wherein the modified material comprises (1) a material comprising a topical carrier, a powder, a coating, or a fabric, and (2) a metal compound comprising a transition metal compound, an actinide compound, a lanthanide compound, or a combination thereof, wherein the metal compound is not a polyoxometalate.
66. The modified material of claim 65, wherein the metal compound comprises a cerium compound, a platinum compound, a silver compound, a gold compound, or a combination thereof.
67. The modified material of claim 65, wherein the metal compound is a gold compound.
68. The modified material of claim 65, wherein the metal compound is a platinum compound.
69. The modified material of claim 65, wherein the metal compound is a cerium compound.
70. The modified material of claim 65, wherein the metal compound is a silver compound.
71. The modified material of claim 65, wherein the metal compound is a cerium compound and a platinum compound.
72. The modified material of claim 65, wherein the metal compound is a cerium

compound and a gold compound.

73. The modified material of claim 65, wherein the metal compound is a silver compound and a gold compound.
74. The modified material of claim 65, wherein the material is a topical carrier and the metal compound is a silver compound.
75. The modified material of claim 65, wherein the topical carrier is a perfluoropolyether and the metal compound is a silver compound, a gold compound, or a combination thereof.
76. The modified material of claim 65, wherein the topical carrier is a perfluoropolyether and the silver compound is AgNO_3 , AgClO_4 , or a combination thereof.
77. The modified material of claim 65, wherein the metal compound comprises (1) gold, copper, and nitrate; (2) gold, iron, and nitrate; (3) gold, manganese, and nitrate; (4) gold, titanium, and nitrate; (5) gold, cobalt, and nitrate; (6) gold and nitrate; (7) copper and nitrate; (8) iron and nitrate; (9) gold, vanadium, and nitrate; (10) gold, nickel, and nitrate; (11) gold, silver, and nitrate; (12) gold, chloride, and nitrate; or (13) cerium compound.
78. The modified material of claim 65, wherein the metal compound comprises gold, chloride, and nitrate.
79. The modified material of claim 65, wherein the metal compound comprises mixing (1) $(\text{NEt}_4)\text{AuCl}_2$ and (2) CuSO_4 , MnSO_4 , VOSO_4 , $\text{Ti}(\text{SO}_4)_2$, $\text{Fe}_2(\text{SO}_4)_3$, NiSO_4 , ZnSO_4 , $\text{Cr}_2(\text{SO}_4)_3$, MgSO_4 , CoSO_4 , $\text{Pd}(\text{NO}_3)_4$, Na_2SO_3 , or NBu_4NO_3 , or a combination thereof.

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80. An article comprising the modified material of claim 65.
81. A method for removing a contaminant from an environment, comprising contacting a modified material of claim 65 with the environment containing the contaminant for a sufficient time to remove the contaminant from the environment.